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Sequence of Quaternary Sediments in the Bélanger Sand Pit, Pointe-Fortune, Québec-Ontario
Séquence de sédiments quaternaires dans la sablière Bélanger, Pointe-Fortune, Québec-Ontario

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Résumé de l'article

Des forages à l'intérieur de la sablière Bélanger (Ontario) près de Pointe-Fortune, Québec, permettent d'ajouter trois unités stratigraphiques à celles déjà visibles à la surface: un till inférieur, et, en position intermédiaire, un ensemble sable-argile avec matière organique(?) recouvert par une argile lacustre. Ces trois unités comprennent près de 70% de la stratigraphie du site et sont recouvertes par une unité de sable et de sable silteux contenant de la matière organique datée à >40 000 ans. Cette dernière est tronquée par une unité de sable non fossilifère, et un till occupe le haut de la coupe. La totalité des sédiments quaternaires forment une séquence de 18 m de haut. La séquence quaternaire de Pointe-Fortune présente des similarités avec la série quaternaire de Trois-Rivières, qui inclut les sédiments de Saint-Pierre d'un âge de plus de 75 000 ans. Cette étude en plus de fournir de nouvelles données sur la stratigraphie démontre que l'utilisation conjointe de techniques directes (forages) et indirectes (géophysiques) s'avère utile à l'interprétation des données stratigraphiques en présentant une image tri-dimensionnelle du terrain. Afin de faciliter de futurs travaux de forage, nous avons établi les propriétés géotechniques de l'argile massive compacte.

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Notes

SEQUENCE OF QUATERNARY SEDIMENTS IN THE BÉLANGER SAND PIT, POINTE-FORTUNE, QUÉBEC-ONTARIO

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ABSTRACT Drilling in the floor of the Bélanger sand pit (Ontario) near Pointe-Fortune, Québec, added 3 stratigraphic units to those already exposed in the pit: a lowermost till, and an intermediate organic-bearing(?) sand-clay unit overlain by a massive lacustrine clay. The subsurface units, comprising about 70% of the stratigraphy, complete the Quaternary sequence exposed in the pit face: an organic-bearing silty sand (>40 000 years BP) unit truncated by an unfossiliferous sand unit and overlain by the uppermost till. The overall sequence forms a continuous 18 m column of Quaternary sediments. The Pointe-Fortune sequence shows some similarities with the Trois-Rivières Quaternary series which includes the Saint-Pierre sediments >75 000 years old. In addition to stratigraphic information the combination of direct (drilling) and indirect (geophysical) methods of investigation by providing a three-dimensional picture of the subsurface has proved helpful in interpreting the stratigraphy. The geotechnical properties of a massive overconsolidated clay have been determined to facilitate the planning of future subsurface investigation.

RÉSUMÉ *Séquence de sédiments quaternaires dans la sablière Bélanger, Pointe-Fortune, Québec-Ontario.* Des forages à l'intérieur de la sablière Bélanger (Ontario) près de Pointe-Fortune, Québec, permettent d'ajouter trois unités stratigraphiques à celles déjà visibles à la surface: un till inférieur, et, en position intermédiaire, un ensemble sable-argile avec matière organique(?) recouvert par une argile lacustre. Ces trois unités comprennent près de 70% de la stratigraphie du site et sont recouvertes par une unité de sable et de sable silteux contenant de la matière organique datée à >40 000 ans. Cette dernière est tronquée par une unité de sable non fossilifère, et un till occupe le haut de la coupe. La totalité des sédiments quaternaires forment une séquence de 18 m de haut. La séquence quaternaire de Pointe-Fortune présente des similarités avec la série quaternaire de Trois-Rivières, qui inclut les sédiments de Saint-Pierre d'un âge de plus de 75 000 ans. Cette étude en plus de fournir de nouvelles données sur la stratigraphie démontre que l'utilisation conjointe de techniques directes (forages) et indirectes (géophysiques) s'avère utile à l'interprétation des données stratigraphiques en présentant une image tri-dimensionnelle du terrain. Afin de faciliter de futurs travaux de forage, nous avons établi les propriétés géotechniques de l'argile massive compacte.

A subsurface investigation program, involving both drilling and shallow geophysical surveys was conducted in the Bélanger sand pit, Ontario, (Fig. 1) near the village of Pointe-Fortune, Québec, during November 1982. The primary objective of the program was to verify the vertical extension below the pit floor of an exposure of subtill organic-bearing sand dated at >41 000 BP (GSC-2932; GADD *et al.*, 1981). The investigation added three stratigraphic units to those already known from the site, from bottom to top: a lowermost till, an organic-bearing(?) sand-clay unit and a massive clay. The sediments exposed in the pit walls and those in the subsurface form an 18 m stratigraphic column comprising 6 units. The Pointe-Fortune site is the first location west of the Richelieu axis in the St. Lawrence Lowland where pre-Late Wisconsin organic sediments have been found. The site, with an intertill clay of probable lacustrine origin, is added to the main intertill glaciolacustrine sites reported by OCCHIETTI (1982) for central Québec. A tentative correlation is proposed with the Trois-Rivières Quaternary series.

Some geotechnical characteristics of the massive clay were determined to assist in the planning of future investigation. This program illustrates the benefits to be derived from the complementary use of direct (drilling) and indirect (geophysical) methods of subsurface investigation applied to stratigraphic problems.

PREVIOUS WORK

The first description of the exposed subtill sediments, then identified as "glaciofluvial" sands in the Bélanger sand pit was by GWYN and THIBAULT (1975). RICHARD (1978) observed sand similar to the subtill sediments reported by Gwyn and Thibault and proposed a subaqueous outwash origin. In 1978 N.R. Gadd and R.J. Fulton found organic remains in the sand and the working face of the pit was then described as "...about 3 m of oxidized till overlying some 6 m of oxidized, stratified, and cross-bedded sand, with some silt bands" (GADD *et al.*, 1981). Bits of wood, compressed and worn, obtained from the sand, yielded a radiocarbon date >42 000 years (GSC-2932). GADD *et al.* (1981, p. 66) relying mainly on the massive structure of the wood-bearing sand and the absence of pebbles in the sediments suggested a depositional environment ..."rapid sedimentation in an environment of deposition such as the broad lake-like expansion of the present Ottawa River". The authors concluded that the Pointe-Fortune subtill sand predated the last glaciation and was of fluvial origin. A possible relationship with the >75 000 year-old Saint-Pierre sediments (GADD, 1971) was suggested.

Subsequent work by S.H. Richard and P.J. Barnett (in 1981 and 1982) yielded two additional dates from the upper portion of the organic-bearing sands: >40 000 BP (GSC-3459) on a single piece of wood, and >38 000 BP (GSC-3444), on flattened twigs. Richard (BLAKE, 1982 p. 6) also pointed out that in September 1981 the working face of the active borrow pit showed a subtill erosional contact in the sand which was not observable before. The organic-bearing sand unit that had yielded the radiocarbon dates was overlain and truncated by a coarser unfossiliferous, crossbedded sand. Richard suggested that the uppermost unfossiliferous sand may have been the only sand unit suitably exposed at the time of his earlier visit (RICHARD, 1978) and that of GWYN and THIBAULT (1975). The pit is active most of the year and

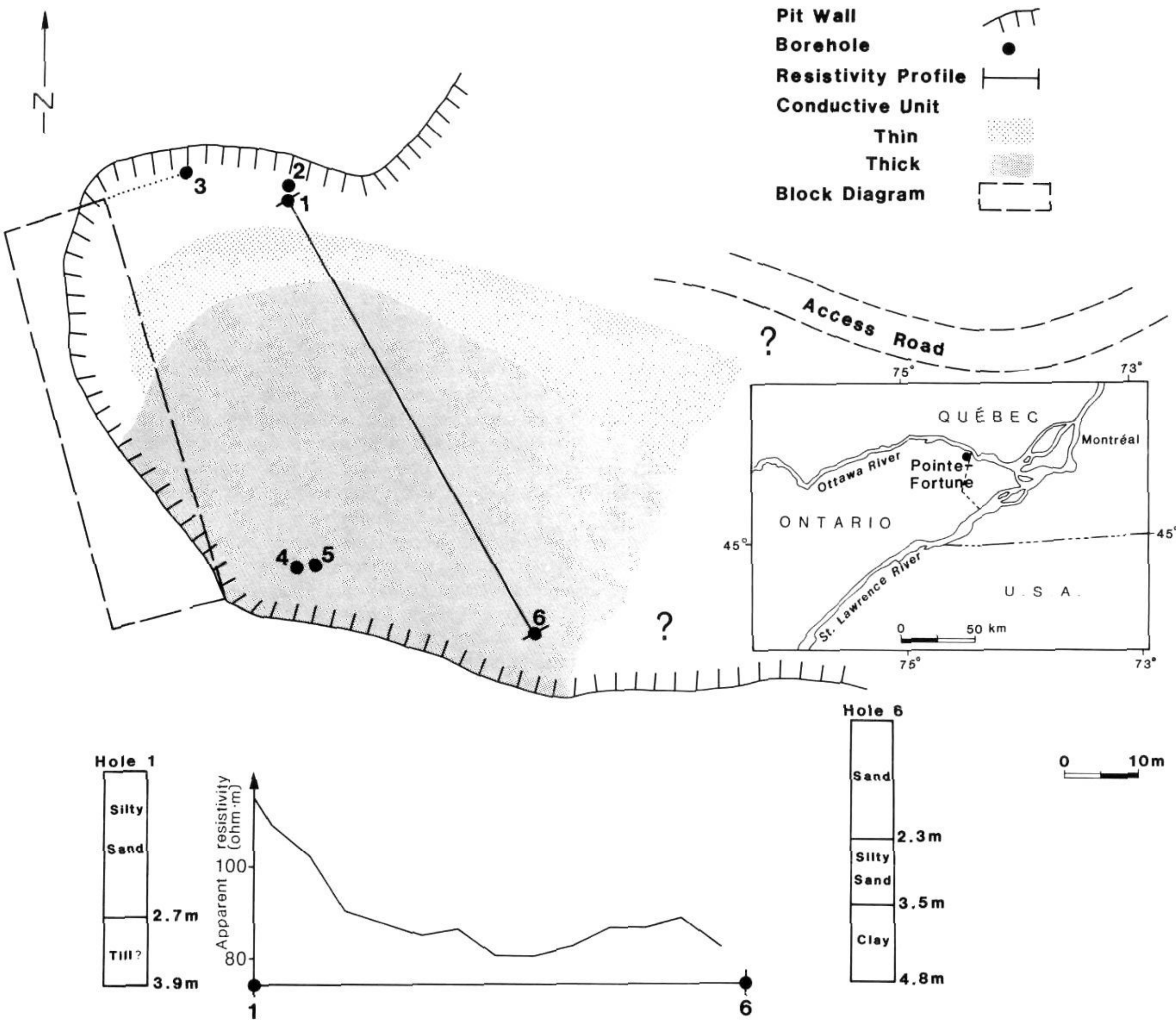

FIGURE 1. Plan view of the western portion of the Bélanger sand pit, Ontario. The map shows the distribution of the clay of unit 3 (conductive unit) in the subsurface, the location of boreholes and a typical electrical resistivity profile. The west end of the pit, in November 1982, was about 200 m west of the N-S road that constitutes the Québec-Ontario border. An outline marks the location of the block diagram of Figure 2.

Vue en plan de la partie ouest de la sablière Bélanger, Ontario. La carte montre la répartition de l'argile de l'unité 3 (unité conductrice) sous la surface, la localisation des forages et un profil type de résistivité électrique. En novembre 1982, l'extrémité ouest de la sablière était à une distance d'environ 200 m à l'ouest de la route N-S qui marque la frontière entre le Québec et l'Ontario. La localisation du bloc-diagramme de la figure 2 est indiquée.

sectors of the pit wall containing organic material may not always have been exposed.

D.R. Sharpe (pers. comm., 1982) visited the site in fall 1982 and confirmed the presence of the two distinct sand units observed by Richard and Barnett in 1981. He measured paleocurrent directions in each sand unit and proposed a subglacial origin for the upper unfossiliterous sand. PRICHONNET (1983; pers. comm., 1982) proposed a fluvial origin in a meandering system for the subtill sands. J.V. Matthews, Jr. supplied preliminary investigation reports on the plant macrofossils and insect remains of the organic-bearing sand (Plant macrofossil reports 78-5, 82-9 and fossil arthropod report No. 82-10). He suggested that the organic zone sampled for plant macrofossil report No. 82-9 represents the deposits of a small floodplain pond. R.J. Mott and T.W. Anderson are carrying out palynological investigation on the organic-bearing sand on the new massive clay unit.

METHODS OF SUBSURFACE INVESTIGATION

Drilling was conducted with Terrain Sciences light-weight hydraulic drill mounted on an all-terrain vehicle (VEILLETTE and NIXON, 1980). For probing and rapid exploration, small diameter (7.5 cm) continuous- flight augers were used. This technique facilitated the discovery of thick unconsolidated sediments, including a clay unit, in the southwest sector of the pit (Fig. 1). A site was selected for detailed investigation in this sector (borehole 5).

The high water table in the pit subsurface necessitated casing of the upper portion of the hole. Rotary drilling using a tricone roller bit (7.5 cm diameter) and circulating a light bentonite mud was combined with split-spoon sampling (3.5 cm core) using a 63 kg drop-hammer. This coring technique was required due to the overconsolidated condition of the fine grained sediments which prevented the use of Shelby tubes. It also permitted the application of the Standard Penetration Test to determine the strenght of the buried clay. Refusal in stony material at 9 m forced a switch to diamond drilling; boring was continued to 11 m using a swivel-type double-walled core cutting a 4 cm core. Only partial recovery of this stony sediment (till) was possible.

Before and after drilling was completed, shallow seismic surveys were conducted in the Bélanger pit by members of the Terrain Geophysics section of the Geological Survey of Canada in spring and fall 1982. (For a description of this technique see HUNTER *et al.*, 1982.) The seismic surveys proved valuable in guiding the drilling program and in complementing its results. The overconsolidated sediments, especially the clay unit, are of interest to geophysicists (seismic) given the high bulk density of over-consolidated compared with normally consolidated clay.

At the completion of the drilling program we carried out a shallow electromagnetic survey between boreholes and away from the drilling sites using the Geonics EM31 terrain conductivity meter. The light-weight, portable instrument allows rapid recording of apparent conductivity of the ground which offers useful information about the subsurface (SINHA and STEPHENS, 1983). Depth of probing is approximately 6 m. From this survey and the information from boreholes a map of the near-subsurface was made. The distribution and relative thickness of conductive units are shown in Figure 1.

THE SEQUENCE OF QUATERNARY SEDIMENTS

It soon became obvious during exploratory drilling that the distribution of sediments in the subfloor was not uniform and that sediments varied both in thickness and in texture. The composite section (18 m) shown in Figure 2 shows the thickest accumulation of unconsolidated sediments (hole 5) found in the subfloor, together with the sediments exposed in the nearby pit face.

UNIT 1, TILL

Dark greyish brown (2.5 Y 4/2 Munsell colour chart), unoxidized silty sand till with little clay, 2.25 m thick. Most cobble and boulder size clasts are carbonates. Striated pebbles were recovered from the core barrel. A count on the 2 mm-2.5 cm fraction of till (obtained from the upper zone of the till in a split-tube) and on some pebbles, showed 37% Shield

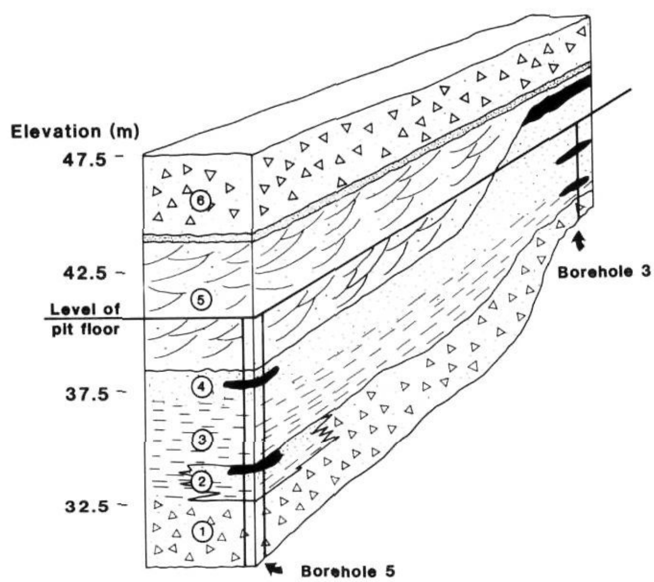

FIGURE 2. Composite (exposed and subsurface sediments) 18 m stratigraphic sequence of the Quaternary sediments at the west end of the Bélanger sand pit: Upper till (6), unfossiliferous sand (5), organic-bearing sand and silty sand (4) massive clay (3) sand-clay, organic-bearing? (2), lower till (1). Black horizons mark concentrations of organic-rich sediments. A planar sandy band separates units 5 and 6. The portion below the pit floor is inferred from boreholes 3 and 5 and from geophysical results.

Séquence stratigraphique de 18 m, composée des sédiments quaternaires en coupe et enfouis à l'extrémité ouest de la sablière Bélanger: till supérieur (6), sable non fossilifère (5), sable et silt contenant de la matière organique (4), argile massive (3), unité de sable et d'argile avec(?) matière organique (2), till inférieur (1). Les horizons en noir indiquent des zones à forte concentration de matière organique. Une bande sablonneuse plane sépare les unités 5 et 6. La portion du bloc-diagramme sous la surface du sol a été reconstituée à partir des forages 3 et 5 et des données géophysiques.

erratics, about 30% carbonates with sandstone and quartzite making up the remainder. Drilling terminated in this unit and 2.25 m is a minimum thickness for unit 1.

UNIT 2, SAND-CLAY

Silty sand in the upper half and massive silty clay in the lower half, about 1 m thick. A horizon of unknown thickness (probably less than 5 cm) containing wood fragments and flattened twigs is suspected at the top of this unit. Undisturbed samples were not recovered for the whole of this unit and consequently its description is not as reliable as that of the other units. Also its relation to the rest of the sequence is not well understood. Unit 2 was encountered only in borehole 5.

UNIT 3, CLAY

Massive silty clay and clay, dark brown to black with scattered tiny shell fragments, very compact, 3.5 m thick (at borehole 5). The clay contains freshwater ostracods (preliminary identification by D. Delorme, Canadian Centre for Inland Waters) and is probably lacustrine. It coarsens upwards towards the sand of unit 4. This transition, from a lacustrine to a fluvial environment, was gradual and suggests a shallowing phase. The clay is considerably overconsolidated. A total carbonate profile in the clay shows a gradual upward decrease of total carbonates in the transitional zone, from clay to sand and sandy silt. A detailed description of the unit is presented in the borehole log of Figure 3.

UNIT 4, ORGANIC-BEARING SAND

Very fine sand and silty sand, mainly horizontally stratified, 1 to 6 m thick. The sand is compact, with grains predominantly subangular, consisting mostly of quartz (>75%). Locally, towards the top of the sequence mainly in the northern part of the pit where this unit is thickest, lenses of massive clay and clayey silt and interbedded sand and silty sand are present.

This unit is characterized by an abundance of organic matter. Organics occur as finely disseminated particles and as twigs, leaves, and wood fragments. Distinct concentrations of organic material are also present in certain zones. Most

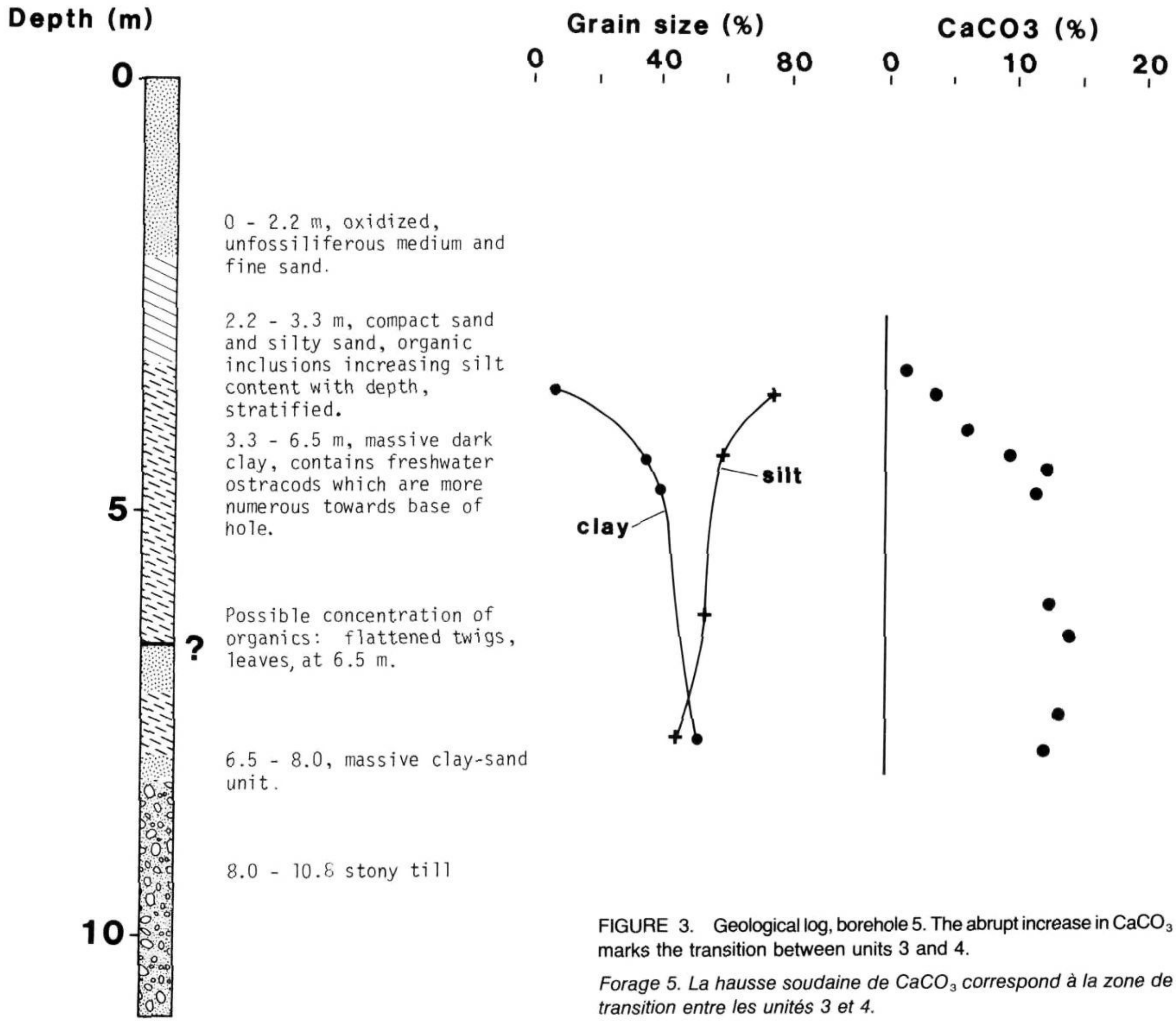

FIGURE 3. Geological log, borehole 5. The abrupt increase in $CaCO_3$ marks the transition between units 3 and 4.

Forage 5. La hausse soudaine de $CaCO_3$ correspond à la zone de transition entre les unités 3 et 4.

of the organics collected and all the radiocarbon dated material are from the northern part of the pit. Drilling along the north wall to depths of 3 to 4 m (holes 1,2,3; Fig. 1) showed that distinct bands of organic-rich material occur at specific levels in the subsurface. A back-hoe trench dug in this sector shows such a band (Fig. 4).

Towards the base there is an upward transition from the massive clay of unit 3 to laminated silt and laminated sand occurring within 1 m.

UNIT 5, UNFOSSILIFEROUS SAND

Medium to fine, crossbedded sand with little or no fines, some compaction, 1 to 6 m thick. The sand is well sorted with grains well rounded to subrounded; quartz accounts for more than 70% of the grains. D.R. Sharpe (pers. comm. 1982) reported that the beds thin upwards and in places form trough crossbeds with ripple sequences. He reported only minor faulting of the beds and a predominant flow direction to the SSE. The unit extends 2 m below the pit floor at the drilling site (Fig. 2). Unit 5 rests on an erosional surface in unit 4.

UNIT 6, TILL

Compact, oxidized, olive-brown (2.5 Y 4/4 Munsell colour chart), stony, sandy till (sand, 69%; silt, 26%; clay, 5% one sample), 1 to 4 m thick. Total carbonate content is 14.5% (one sample). A count on 100 pebbles: white quartzite 52%, sandstone 21%, carbonates 4%, Shield erratics 23%. The till is fissile, and locally angular sand lenses appear associated with shear planes. Numerous slope failures observed at the working face during a 2-week period in November 1982 showed that the till has a blocky structure and fails along near-vertical and oblique joints. D.R. Sharpe (pers. comm., 1982) described an undeformed and planar zone of contact between the till and the sandy unit below. It consists of a thin transitional (<30 cm) band showing interbedding of sand and till with inclusions and lenses of crossbedded fine sand. The contact between units 6 and 5 is planar and exceptionally uniform (Fig. 5).

THE UPPER AND LOWER TILLS COMPARED

Although the amount of material sampled from the lower till is limited, comparison between the two till units indicates differences in their respective proportions of carbonates and Shield erratics, in their heavy mineral content and degree of oxidation, and to a lesser extent in their colour. The bedrock geology map (GLOBENSKY, 1983) shows that the Bélanger pit is underlain by the Theresa Formation (sandstone and dolomite) or by the Beauharnois Formation (dolomite, limestone and shale). Globensky put a contact between these two Ordovician Formations of the Beekmantown Group, under the pit or in its immediate vicinity. The proportions of carbonates in the lower till (30%) is more indicative of a nearby source of carbonate rocks than that of the upper till (4%). The main characteristic of the upper till is its high proportion of quartzite (52%) and sandstone (21%). White quartzite sandstone from the Cairnside Formation, Postdam Group (Cambrian), occurs within 2 km E and NE of the Bélanger pit, but is not reported to the W and NW of the pit. Both tills have a significant content of Shield erratics: 23% for the upper and 37% for the lower till. An outlier of Precambrian crystalline rocks, about 6 km in diameter occurs about 3 km E and NE of the Bélanger pit and could be the source area for most of the Shield erratics. The Precambrian Shield is 14 km north of the pit. The lithological composition suggests that both tills had a NNE provenance.

The heavy mineral composition based on two samples from each till, is shown in Figure 6. Garnet is abundant in

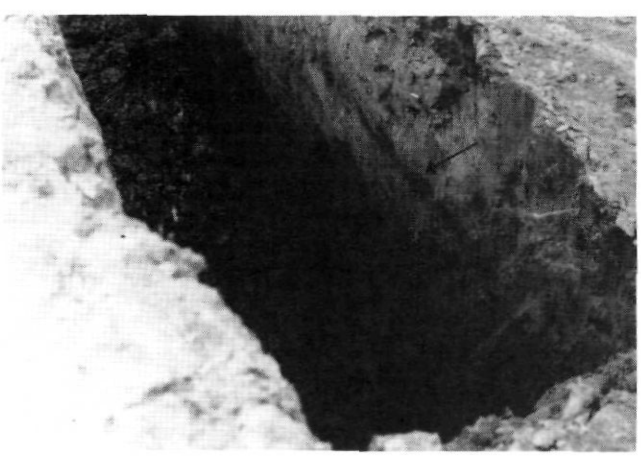

FIGURE 4. Organic-rich band (arrow) in back-hoe trench along the north wall of the Bélanger sand pit. Note collapse in the water-saturated sand below the water table. Photo courtesy of N.R. Gadd.

Zone riche en matière organique (flèche) exposée dans une tranchée près de la limite nord de la sablière Bélanger. Noter l'affaissement dans le sable gorgé d'eau sous la nappe phréatique. La photo est de N.R. Gadd.

FIGURE 5. Exposed section of the west end of the Bélanger pit in mid-November 1982. The drill is at borehole 5. Note planar contact between the upper till (unit 6) and the unfossiliferous sand (unit 5), GSC photo No. 203990-G.

Coupe à l'extrémité ouest de la sablière Bélanger, mi-novembre 1982. La foreuse est au site du forage 5. Noter la zone de contact planaire entre le till supérieur (unité 6) et le sable non fossilifère (unité 5). CGC photo n° 203990-G.

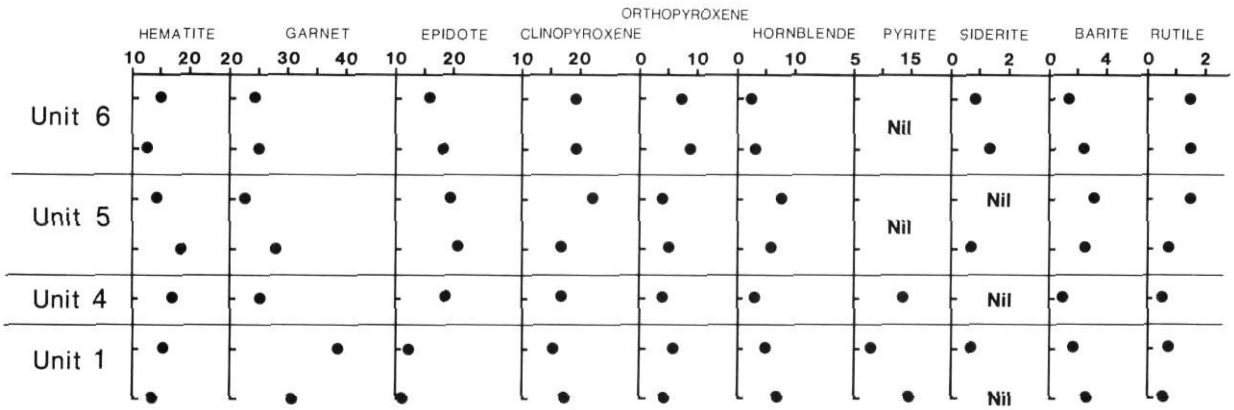

FIGURE 6. Heavy mineral composition (percentage) in units 6 (2 samples), 5 (2 samples), 4 (1 sample) and 1 (2 samples).

Pourcentage de minéraux lourds dans les unités 6 (2 échantillons), 5 (2 échantillons), 4 (1 échantillon) et 1 (2 échantillons).

both tills, reaching nearly 40% in the lower till. Garnet gneiss of the Grenville Series is one of the rocks composing the Precambrian outlier to the east referred above (GLOBENSKY, 1983) and could explain the abundance of garnet in the tills. Pyrite reaches a maximum of 15% in the lower till but is absent from the upper till. This difference may indicate a different provenance for the two tills but may also be due to weathering out of the pyrite in the upper till or other local bedrock conditions.

ICE FLOW DIRECTIONS AND THE TWO TILLS

A SW direction of ice flow is indicated for the lower till based on the high content of Shield erratics and the high garnet content. However, this evidence is too limited to propose a direction of ice flow associated with the lower till.

Although ice flow data associated with the upper till is available from different sources, it is difficult to assign on the basis of these sources a particular ice flow direction with the upper till at the Bélanger pit. Till fabric measurement by PRICHONNET (in press) suggests a flow from the NNW. D.R. Sharpe (pers. comm., 1982) reported major fabric elements (boulders) oriented east-west in the till. GWYN and THIBAULT (1975) did till fabric measurements in the Bélanger pit and at other locations within 5 km; although they did not propose an ice flow direction associated with the upper till, their measurements at 2 of the 3 sites show a preferred pebble orientation NNE-SSW.

Striations and movement of distinctive Shield erratics have shown that complex ice flow occurred in the general area (GADD, 1980). Two main directions of striations were recorded: one to the SSW (older) the other to the SE (younger). Gadd indicated that the SE flow was "residual" or secondary, producing only a light polish on more heavily striated surfaces indicating major or maximum flow toward the S and SW. The presence of distinctive Shield erratics (anorthosite) indicates a direction of transport to the SW for the region, which is supported by the pebble lithology reported here. A zone of converging striations, possibly associated with an interlobate position, has been recognized by GADD (1980) west of Montréal Island. It is suggested here that the SE component of ice flow around Pointe-Fortune, as revealed by striations measured by Gadd resulted from a last ice movement towards this interlobate position, but that the SW component of flow is largely responsible for the transport of glacial debris in the upper till. PRICHONNET (1977) on the other hand, has also observed cross striated bedrock surfaces in the general area and claims that the SW component of ice flow postdates the SE component.

A recent till stratigraphy and ice flow indicators study in the Malone area of the St. Lawrence Lowland, New York (CLARK and KARROW, 1983) complements the striations measurements made by GADD (1980) in the adjacent region north of the St. Lawrence River. The projection, north of the St. Lawrence River, of ice flow lines suggested from patterns of striations in the Malone area indicates a zone of ice flow convergence (SE-SW) centered in the vicinity of Cornwall, Ontario. Based on this model, on the striation pattern reported by GADD (1980) and on the lithological composition of the surface till at Pointe-Fortune, a SSW ice flow direction is proposed at the Bélanger site. CLARK and KARROW (1983) demonstrated that a single till sheet exists in the Malone-Fort Covington area and proposed that the term Malone Till be discontinued. This is in contradiction with the work of MacCLINTOCK and STEWART (1965) who defined two surface tills (Fort Covington and Malone) for the same area. This new data prompts a reassessment of the origin of the surface till on the Canadian side where, since MacCLINTOCK and STEWART (1965), the presence of two tills (TERASMAE, 1965, PREST and HODE-KEYSER 1977) has been accepted.

SUMMARY OF EVENTS

The extended stratigraphy in the Bélanger pit adds to the work of RICHARD (1978), GADD *et al.* (1981), D.R. Sharpe (pers. comm. 1982) and PRICHONNET (1983, in press) on the exposed portions of the subtill sands. These investigators basically proposed fluvial systems to explain the organics present in unit 4. Sharpe supplied specific information on the two subtill sand units. He suggested that the unfossiliferous sand (unit 5) results from a subglacial stream in a tunnel which filled up with sand in a manner similar to that described by SHAW (1982) for subtill sediments exposed in borrow pits near Edmonton, Alberta. If this is the case the composition of the unfossiliferous sand should be closely related to that of the upper till (unit 6). The lack of major differences in heavy mineral composition between the upper till and the unfossiliferous sand (Fig. 6) supports this interpretation, which also has the advantage of offering a reasonable explanation for the sharp planar contact between the two units. On the other hand the base of the unfossiliferous sand is oxidized at borehole 6; this is difficult to explain in a subglacial environment. An alternate explanation is that this weathering zone results from groundwater action. If, as suggested by D.R. Sharpe, unit 5 is primarily a deglaciation feature, then the erosive contact between unit 5 and unit 4 (older than 40 000 years) could represent a major time lag in the depositional record.

Reports by J.V. Matthews, Jr. (see section on Previous Work in this report) on autochthonous plant macrofossils and insect remains collected near the top of unit 4 indicate that ponding without disturbance by flowing water was present at this level. Further down in unit 4 a sample obtained from a back-hoe trench (GADD *et al.*, 1981) produced allochthonous organics within the alluvial sands (J.V. Matthews, Jr., plant macrofossil report 78-5). Matthews proposed a floodplain environment for this lowermost sample.

The relatively thin zone of transition (1 m) observed in the core between units 3 and 4 with no detectable hiatus in sedimentation and with an abrupt change in total $CaCO^3$ content suggests a fairly rapid passage from lacustrine to a higher energy environment. Units 3 and 4 are then probably closely related in time.

Terrestrial organics, encountered in borehole 5, appear to occur below unit 3, and are likely the oldest sediments at the site. The presence of organics and sandy sediments at this level (unit 2) makes it difficult to consider an environment of sedimentation proximal to the glacier for the massive clay unit (unit 3). The absence of varves in the clay also argues against proximity of the glacier. The massive clay could represent sedimentation in a temporary freshwater lake in an abandoned channel within a large fluvial system. More information on the exact nature of the freshwater ostracods (cold or warm environment) would be helpful to determine the type of lacustrine deposits that unit 3 represents.

Finally the till of unit 1 separated from the upper till by about 12 m of nonglacial sediments with an age >40 000 years definitely marks a different glacial event than that of the upper till.

THE POINTE-FORTUNE QUATERNARY SEQUENCE AND THE TROIS-RIVIÈRES SERIES

The Pointe-Fortune site constitutes the first occurrence of two distinct tills and intertill organic-bearing sediments west of Lac Saint-Pierre where GADD (1971) first reported intertill sediments >75 Ka. It should be remembered that the complete sequence of Quaternary sediments at Pointe-Fortune is not yet known, since drilling has not reached bedrock. Furthermore, most of the direct information in the subsurface, which contains close to 70% of the known stratigraphy, results from a small-diameter core. Also, unfortunately, future information on the sediments at the site probably will have to rely on drilling. Despite this limiting factor a correlation of the Pointe-Fortune sediment sequence with the Trois-Rivières sequence (OCCHIETTI, 1982; GADD, 1971) can be tentatively proposed.

At both localities the lowermost till — Bécancour (Trois-Rivières) and unit 1 (Pointe-Fortune) — shows significant Shield erratic contents. This is the only point of comparison since the Bécancour Till was described from sections and the Pointe-Fortune Till was revealed by drilling. Stratigraphic position is the only valid critera to correlate the two tills. Both tills are overlain by fine grained lacustrine sediments which, however, show substantial differences. Distinctly varved sediments (Pierreville Varves) occur in the Trois-Rivières series while massive clay, containing freshwater ostracods (unit 3), occurs at Pointe-Fortune. Is the clay of Pointe-Fortune part of a larger lacustrine basin or does it result from local ponding associated with the fluvial sediments overlying it? The latter hypothesis seems more likely with the evidence at hand.

Since organic remains probably occur at the base of unit 3 or even in unit 2, it is possible that units 2, 3 and 4 of Pointe-Fortune are the equivalent of the fluvial, lacustrine and organic sediments of Saint-Pierre. The three infinite radiocarbon ages (see previous work section) obtained from unit 4, and the fact that organic material (not dated) occurs further down (below unit 3) in the sequence leave open the possibility that the sediments could be comparable in age to the Saint-Pierre sediments dated at 74 700 ± 2700 BP (STUIVER *et al.*, 1978).

Further up the sequence the Gentilly Till of the Trois-Rivières series probably correlates with the upper till of Pointe-Fortune (unit 6) referred to as the Fort Covington Till (GWYN and THIBAULT, 1975). The unfossiliferous sand (unit 5) below the till is either closely related to this till as proposed by Sharpe or, as suggested by PRICHONNET (in press), it may result from channel cutting associated with a meandering river. In this latter case unit 5 would be more closely related to the underlying units.

GEOTECHNICAL PROPERTIES AND AREAL EXTENT OF THE CLAY (UNIT 3)

Because drilling or excavation with heavy equipment is the only method to sample adequately the three subsurface units and the basal parts of two exposed units, a knowledge of the behaviour of the material is useful for planning additional investigation. Coring is probably the most suitable method since excavation with heavy equipment is hampered by a high water table. Although all sediments drilled through at the Pointe-Fortune site show some signs of compaction, the clay (unit 3) shows best the overconsolidated condition of the subsurface. In a normally consolidated sediment, void ratio and water content decrease with depth while soil strength increases. The Pointe-Fortune clay does not follow this pattern and, for this reason and others discussed below, is believed to be greatly overconsolidated.

The clay has been loaded by the glacier associated with the upper till and by the subtill sediments above the clay. The stress history is identifiable (Fig. 7) by the following criteria:

(1) Over the whole profile, the clay exhibits a uniform water content (around 25%).

(2) The natural water content is in the vicinity of the plastic limit for all samples.

(3) Standard Penetration Tests indicate a very high resistance to penetration which does not change significantly with depth. Five tests in the clay gave N values (N = number of drop-hammer blows required to advance the tube 30 cm) ranging from 90 to 205. A clay is considered hard (unconfined compressive strength greater than 3.90 kg/cm^2) if a N value greater than 30 is recorded (LAMB and WITHMAN, 1969). The Pointe-Fortune clay (N = 90 to 205) has thus a considerable strength which could be of interest to geotechnicians.

(4) Upon drying for several days in the laboratory the clay core showed only minor cracking.

The Pointe-Fortune clay could, provided undisturbed samples were recovered, be used to infer ice thickness in a manner similar to that used by ROALDSET (1980). He inferred ice thickness over subtill clays in Herlandsdalen, south Norway, using curves developed by SKEMPTON (1953). These curves are based on the relationship between void ratio and effective overburden pressure for clays of different liquid limits. Void ratio values could not be obtained with certainty from the Pointe-Fortune core because the hardness of the clay prevented the use of Shelby tubes which are necessary in order to recover undisturbed samples. This could probably be remedied by the use of heavier drilling equipment or by a modified rotary drilling method.

Clay activity (A = Plasticity Index/clay fraction) is of some value for geological correlations. SKEMPTON (1953)

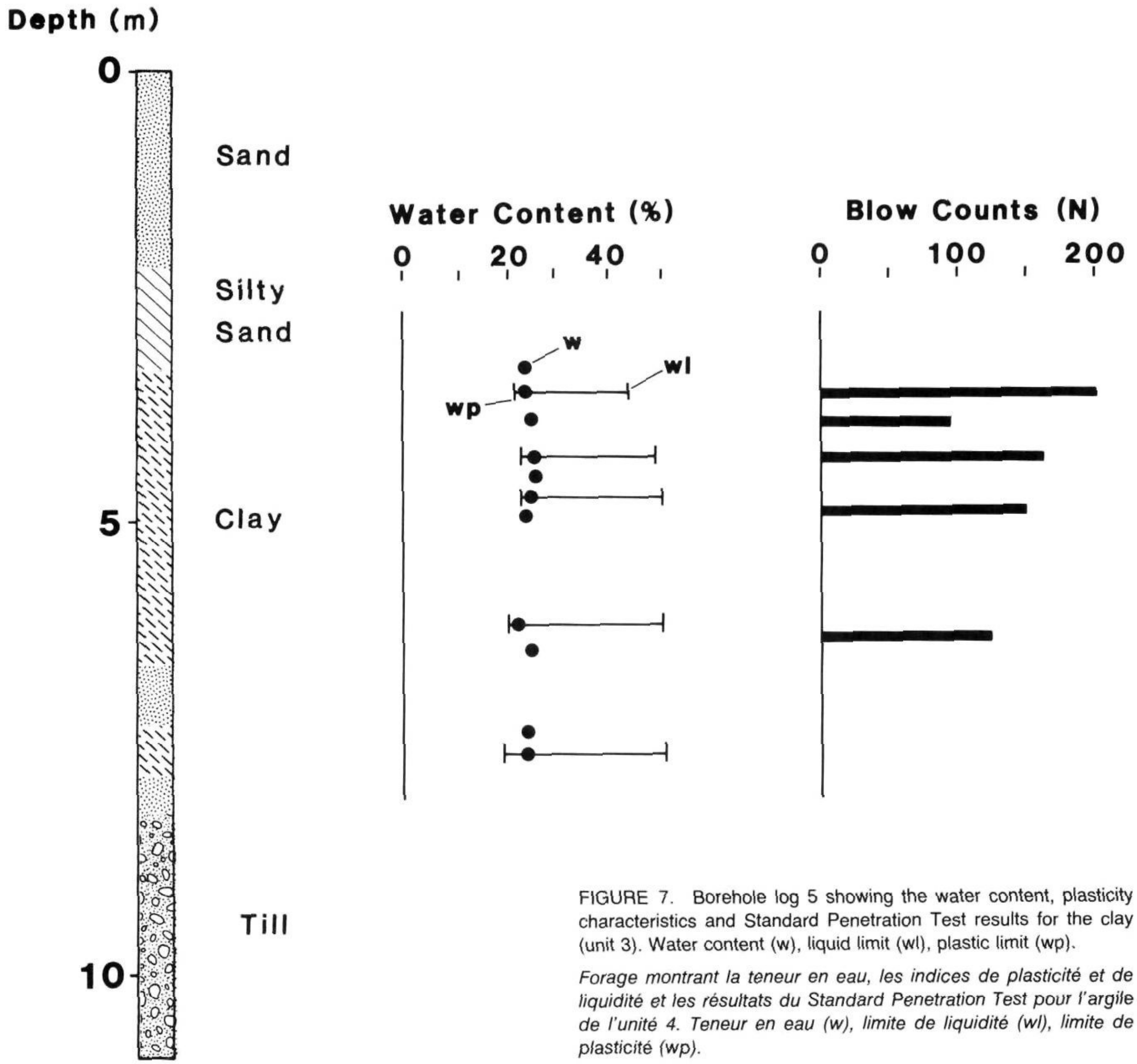

FIGURE 7. Borehole log 5 showing the water content, plasticity characteristics and Standard Penetration Test results for the clay (unit 3). Water content (w), liquid limit (wl), plastic limit (wp).

Forage montrant la teneur en eau, les indices de plasticité et de liquidité et les résultats du Standard Penetration Test pour l'argile de l'unité 4. Teneur en eau (w), limite de liquidité (wl), limite de plasticité (wp).

recognized four broad groups of clay activity related to specific sedimentary environments. The clay of the Bélanger pit has activity values of 0.67, 0.68 and 0.57 (3 samples) and belongs to group B of Skempton — activity 0.5 to 0.75 — which includes lacustrine and brackish water. This is in accord with the biological evidence (ostracods) indicating a freshwater origin for the clay.

A freshly deposited clay has a water content approximately equal to its liquid limit (SKEMPTON, 1953). Applying this to the clay of unit 3, which has a liquid limit in the vicinity of 50% and a water content near 25%, the clay underwent a volumetric decrease of around 30% (specific gravity of soil 2.74). It could have been as thick as 6 m before overconsolidation took place. Such a thickness argues for a substantial body of water. The owner of the pit, Mr. A. Bélanger, after seeing core samples of the overconsolidated clay of unit 3, found a strong similarity with a stiff clay encountered during excavation for a nearby service road to the Trans-Canadian highway. Geophysicists of Terrain Geophysics, Geological Survey of Canada (J. Hunter, R. Gagné, R. Good, R. Burns, pers. comm. 1982) consider the specific seismic response of the overconsolidated clay an aid to facilitate its mapping using seismic methods.

The map of the Bélanger pit (Fig. 1) shows these sectors of the subsurface where the most complete sequence of Quaternary sediments is expected. The uneven bedrock topography and subsequent differences in unconsolidated sediment distribution and thickness makes the map a useful document to plan a subsurface investigation program. The level of the bedrock floor inferred from seismic surveys is close to the surface (3-4 m) in the NW corner of the pit but is buried by as much as 25 m of unconsolidated sediments 120 m S and E of the NW corner. Geophysical data also indicate that the sand of unit 5 thickens towards the south and toward the eastern end of the pit. Seismic soundings indicate deep bedrock in the NE sector of the pit. Data is however too scarce in this area to speculate on the nature of the sediments. With the results at hand, future work aimed at the study of Quaternary sediments should be concentrated in the S and SW portions of the pit.

RESULTS AND NEED FOR FUTURE WORK

1. Drilling added three stratigraphic units to 3 units already exposed in the Bélanger sand pit near Pointe-Fortune, Québec: a lowermost till and an intermediate organic-bearing(?) sand-clay unit overlain by a massive lacustrine clay unit. About 70% of the stratigraphy at the site lies below the pit floor. A composite section of the exposed and buried sediments form a 18 m stratigraphic column.

2. The new data added to the results presented by GADD *et al.* (1981), to preliminary reports on plant macrofossils and insect remains by J.V. Matthews, Jr. and to radiocarbon ages from samples collected by S.H. Richard (BLAKE, 1982) suggest strong similarities in sedimentary environments between the Pointe-Fortune site and the Trois-Rivières Quaternary series (OCCHIETTI, 1982) which includes the Saint-Pierre sediments dated at >75 000 years old (GADD, 1971).

3. Comparison of results from different investigators concerning the ice flow direction associated with the upper till at Pointe-Fortune led to some confusion. The lithological composition of the till at the site, regional striations patterns and relative chronology of movements from GADD (1980) and extrapolation of ice flow lines drawn from patterns of striations in the Malone area by CLARK and KARROW (1983) suggest a SSW direction of ice flow for the upper till.

4. A map of the near-surface in the sand pit derived from drilling and geophysical data shows the known extent of the buried clay (unit 3). The combination of direct (drilling) and indirect (geophysical) methods of investigation by providing a 3-dimensional view of the subsurface have proved helpful in interpreting the stratigraphic sequence.

5. The geotechnical properties of the massive clay unit (unit 3) show the sediment to be greatly overconsolidated. Expulsion of pore water has reduced the water content of the clay to its plasticity limit. Despite a water table near the level of the pit floor, boring through the clay can be done without the need for casing. This condition should facilitate future subsurface investigation at the site.

6. In order to collect adequate amounts of buried organic remains for macrofossils study and to secure a continuous undisturbed core in all Quaternary units above the lower till (unit 1), a large diameter core (medium diameter 7.6 cm) is required.

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REFERENCES

BLAKE, W., Jr. (1982): *Geological Survey of Canada, Radiocarbon dates XXII*, Geological Survey of Canada, Paper 82-7, 22 p.

CLARK, P. and KARROW, P.F. (1983): Till stratigraphy in the St. Lawrence Valley near Malone, New York; Revised glacial history and stratigraphic nomenclature, *Geological Society of America Bulletin*, Vol. 94, p. 1308-1318, 12 figs., 2 tables.

GADD, N.R., RICHARD, S.H. and GRANT, D.R. (1981): Pre-last-glacial organic remains in Ottawa Valley, *in Current Research, Part C*, Geological Survey of Canada, Paper 81-1C, p. 65-66.

GADD, N.R. (1971): *Pleistocene geology of the central St. Lawrence Lowland*, Geological Survey of Canada, Memoir 359.

——— (1980): Ice flow patterns, Montreal-Ottawa Lowlands areas, *in Current Research, Part A*, Geological Survey of Canada, Paper 80-1A, p. 375-376.

GLOBENSKY, Y. (1983): *Région de Lachute*, Ministère de l'Énergie et des Ressources, Service des levés géologiques, rapport géologique -200, 67 p. avec carte nº 1966.

GWYN, Q.H.J. and THIBAULT, J.J.L. (1975): *Quaternary geology of the Hawkesbury-Lachute area, southern Ontario*, Ontario Division of Mines Preliminary Map P1010, Geological Series.

HUNTER, J.A., BURNS, R.A., GOOD, R.L., MacAULAY, H.A., and GAGNÉ, R.M. (1982): Optimum field techniques for bedrock reflection mapping with the multichannel engineering seismograph, *Geological Survey of Canada*, Paper 82-1B, p. 125-129.

LAMB, T.W. and WHITMAN, R.V. (1969): *Soil Mechanics*, Series in Soil Engineering, John Wiley, 553 p.

MacCLINTOCK, P., and STEWART, D.P. (1965): *Pleistocene geology of the St. Lawrence Lowlands*; New York State Museum and Science, Service Bulletin 394, 152 p.

OCCHIETTI, S. (1982): Synthèse lithostratigraphique et paléoenvironnements du Quaternaire au Québec méridional. Hypothèse d'un centre d'englacement wisconsinien au Nouveau-Québec, *Géologie physique et Quaternaire*, Vol. XXXVI, Nos. 1-2, p. 15-49.

PREST, V.K. and HODE-KEYSER, J. (1977): *Geology and Engineering characteristics of surficial deposits, Montreal Island and vicinity, Quebec*, Geological Survey of Canada, Paper 75-27, 29 p.

PRICHONNET, G. (1977): La déglaciation de la vallée du Saint-Laurent et l'invasion marine contemporaire, *Géographie physique et Quaternaire*, Vol. XXXI, Nos. 3-4, p. 323-345.

——— (1983): La séquence sédimentaire wisconsinienne de Pointe-Fortune, Québec/Ontario, *Résumé des communications*, 51e congrès de l'ACFAS, vol. 50, p. 122.

——— (in press): Glaciations d'inlandsis: séquences glaciaires, proglaciaires et non glaciaires du Quaternaire de l'est Canadien, *Bulletin Centre de Recherches Expl. Prod. Elf-Aquitaine*, Vol. 8, No. 1, 35 p., 17 fig.

RICHARD, S.H. (1978): Age of Champlain Sea and "Lampsilis Lake" episode in the Ottawa-St. Lawrence Lowlands, *in Current Research, Part C*, Geological Survey of Canada, Paper 78-1C, p. 23-26.

ROALDSET, E. (1980): Overconsolidated sub-till clays in Herlandsdalen, lower Numedal, south Norway, *Norsk Geologisk Tidsskrift*, Vol. 60, p. 39-51.

SHAW, J. (1982): Melt-out till in the Edmonton area, Alberta, Canada, *Canadian Journal of Earth Sciences*, Vol. 19, p. 1548-1569.

SINHA, A.K., and STEPHENS, L.E. (1983): Permafrost mapping over a drained lake by electromagnetic induction methods, *in Current Research*, Part A, Geological Survey of Canada, Paper 83-1A, p. 213-220.

SKEMPTON, A.W. (1953): Soil mechanics in relation to geology, *Proceedings Yorkshire Geological Society*, Vol. 29, No. 1, p. 33-62.

STUIVER, M., HEUSSER, C.J., and YANG, I.C. (1978): North American glacial history extended to 75 000 years ago, *Science*, 200, p. 16-21.

TERASMAE, J. (1965): *Surficial geology of the Cornwall and St. Lawrence Seaway Project areas, Ontario*, Geological Survey of Canada, Bulletin 121, 54 p., Map 1175A.

VEILLETTE, J.J. and NIXON, F.M. (1980): *Portable drilling equipment for permafrost sampling*, Geological Survey of Canada, Paper 79-21, 35 p.